PIPER, WILLIAM. Effects of Interfood Interval on Discrete-Trial Fixed-Time Schedules. (1977)
Directed by: Dr. Aaron J. Brownstein. Pp. 30.

The effects of a constant trial to intertrial ratio on the maintenance of responding on a non-contingent discrete trial fixed interval schedule were investigated. The interfood interval was divided into seven key light illumination separated by periods of no key light. Previous research had demonstrated a change in response patterning as the intertrial interval duration increased with trial duration remaining constant. Early trial responding was observed to increase as interfood interval increased. In this study as interfood interval increased, the trial to intertrial ratio remained constant. A similar pattern emerged, i.e., an increase in responding on early trials as a function of interfood interval. These findings are discussed in terms of a balancing of costs associated with discrimination on the basis of passage of time and discrimination involving the liklihood of food following discrete trials.

EFFECTS OF INTERFOOD INTERVAL ON DISCRETE-TRIAL FIXED-TIME SCHEDULES

by

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A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

Greensboro
1977

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ACKNOWLEDGEMENTS

The author gratefully acknowledges the invaluable guidance throughout all phases of the research and preparation of this manuscript by Dr. Aaron J. Brownstein. The author appreciates the helpful suggestions and interest shown by Dr. Peter Balsam, Dr. Anthony DeCasper, Dr. Cheryl Logan and Dr. Richard Shull.

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CHAPTER I

INTRODUCTION

The typical pattern of responding generated by a fixed interval schedule of reinforcement consists of a post reinforcement pause followed by a period of positively accelerated responding. This pattern is consistent with a temporal discrimination interpretation of FI performance. Several lines of evidence suggest that the temporal patterning on fixed interval schedules is not controlled so much by the absolute duration of the interval, as by the relative time elapsed in the interreinforcement interval (Dews, 1969; Jenkins, 1970; Shull & Brownstein, 1975; Staddon, 1972). Control by relative time is suggested by the fact that the pattern of responding remains generally unaffected by changes in absolute time across a wide variety of interval durations when the response measure is plotted as a function of relative elapsed time (Dews, 1970; Schneider, 1969; Shull, 1971).

Various discrete trial procedures have been used to analyze the temporal control of responding on FI schedules. Such procedures offer the advantage of allowing the investigator to more accurately specify the number and spacing of responses in the interreinforcement interval. Wall (1965), for example, employed a discrete trial procedure in an analysis of the determinants of the FI pattern of bar pressing in rats. A

retractable lever was presented twice during each interval. The first presentation occurred either early, midway, or late in the interval, and responding at this time was not reinforced. A second presentation, followed by food contingent on a response, occurred at the end of each interval. Response latency measures approximated the equivalent of a fixed interval pattern, with latencies decreasing as time to reinforcement approached. Dews (1962) alternated 50-second periods of houselight-on presentation with the same period of houselight-off during a fixed interval 500 seconds. Though overall response rate was less than that for continuous houselight presentation, the scallop pattern remained. Jenkins (1970) manipulated sequences of reinforced and non-reinforced discrete trials in assessing the role of temporal generalization and delay of reinforcement in fixed interval schedules. Again, the typical patterns of responding were observed. Nevin (1969), in a study of matching, used discrete trial fixed intervals each consisting of seven brief key light illuminations separated by fixed periods of no key light. Reinforcement was contingent on a peck on the seventh trial. The probability of a response increased over the seven trials, analagous to the fixed interval scallop. Schneider and Neuringer (1972) used a similar discrete trial analogue to a fixed interval with pigeons. Following a fixed number of four second key light presentations, reinforcement became available contingent on the next response to the lighted key. Each subject was exposed to six different interfood interval lengths. The number of trials prior to reinforcement increased in proportion to the interreinforcement

interval. The temporal patterning, characterized by a low probability of responding immediately after reinforcement followed by an abrupt transition to a higher probability approximately half way through the interval. Response latencies varied in a corresponding way. These patterns remained relatively constant across all interfood interval durations. Heinz and Eckerman (1974) used a similar procedure while measuring changes in response latency and frequency as a function of number of trials, trial duration, and interreinforcement interval duration. As was the case with most of these procedures, only one response per trial was permitted and latency measures again showed patterns of responding similar to those generated by the free-operant fixed interval procedures. Analysis of response frequency data, however, showed that trial responding varied as a function of the number of trials per interval and the duration of the interreinforcement interval.

Analyses of these and similar experiments indicate that chaining of responses is not the controlling factor in the temporal pattern of responding. The disruption of continuous responding, frequently breaking the chain with subsequent responses, does not alter the temporal pattern. Nor is direct reinforcement of interresponse times viewed as a major determinant of such patterns (Dews, 1970). The possibility remains however, that the pattern is maintained by differences in the relative delay between response and reinforcer in successive parts of the interval (Catania, 1970; Dews, 1970; Jenkins, 1970). That is,

in response-contingent situations, the responses occuring at the end of the interval are more immediately reinforced, while responses occurring early in the interval are reinforced only after a long delay. Such differences among the relative positioning of responses in the interval with respect to the reinforcing event have thus been suggested to account for the characteristic pattern of responding.

Recent analyses of key pecking behavior have suggested that birds approach and interact with events that signal the presentation of grain, and avoid those events that signal its absence (see Hearst and Jenkins, 1975, for a review). In the typical autoshaping or sign-tracking procedure, following a number of brief illuminations of a response key paired with food presentations, pigeons quickly acquire key pecking behavior. High rates of performance have been acquired and maintained across a wide variety of trial and intertrial durations. Similar high rates of responding are observed even when keypecking actually results in the cancellation of food presentations (Williams and Williams, 1969). These findings suggest that behavior attributed to a response-reinforcer contingency may often, though perhaps inadvertantly, be the result of a stimulus-reinforcer contingency. In addition, the relative proximity of stimulus and reinforcer is important not only in free operant situations, but also in sign-tracking paradigms as well (Balsam, 1976; Gibbon, Baldock, Locurto, Gold, & Terrace, 1976; Groves, 1975; Hearst & Jenkins, 1974; Terrace, Gibbon, Farrel, & Baldock, 1975).

Brownstein and Wetherington (1975a, 1975b) and Brownstein, Wetherington, and Fifer (1977) reported that stimulus-reinforcer correlations in the absence of experimenter specified response-reinforcer contingencies may produce patterns of responding similar to those evident in response contingent discrete trial procedures. In all of these studies the interreinforcement interval was divided into seven brief key light illuminations separated by fixed periods of no key light, as in the Nevin (1969) study. However, in the Nevin procedure, grain was presented contingent on whether or not a response was made. In the Brownstein and Wetherington (1975b) study the interfood interval was manipulated by varying the time between trials. Seven two-second presentations of key light were separated by trial durations of 5, 15, or 30 seconds. Thus, following interfood intervals of 49, 119, or 224 seconds food was presented whether or not a response was made. Under these conditions for all subjects the temporal pattern was maintained across all interfood intervals. However, as the duration of the intertrial interval was increased, subjects showed a disproportionate increase in the tendency to respond early in the interfood interval. This result appears inconsistent with the notion that relative elapsed time controls responding.

The demonstrated effects of varying trial to intertrial ratio in the previously referred to autoshaping research have also implicated relative rather than absolute trial and intertrial times as the controlling factor in acquisition and maintenance of key pecking. The present study was designed to

determine whether the temporal patterns observed in the Brownstein and Wetherington (1975b) study are controlled by the proportion of trial length to intertrial interval length. If so, with the constant trial to intertrial proportion, the disproportionate early trial responding should disappear.

CHAPTER II

METHOD

Subjects

Six white Carneaux pigeons with no previous history of experimenter specified response-reinforcer contingencies served as subjects. The birds had participated in previous experiments assessing the effects of trial and intertrial lengths in autoshaping and negative automaintenance paradigms. All subjects were maintained at approximately 80% of their free feeding weights throughout the experiment.

Apparatus

The apparatus consisted of two homemade versions of a standard experimental pigeon chamber. One chamber measured 29 cm by 29 cm by 32 cm. The response key employed as the manipulandum was located 8 cm to the right of the food hopper and 24 cm above the floor of the chamber. General illumination was provided by 3 individual GE #1829 bulbs. Two of these bulbs were located in the upper right corner of the chamber and a third bulb was located in the center of the chamber ceiling. The second chamber measured 35 cm by 34 cm by 32 cm, and the response key employed as the manipulandum was located 10 cm to the right of the hopper and 25 cm above the floor. General illumination in this chamber was provided by 2 Sylvania 28PSB bulbs located on the chamber ceiling.

In both chambers the house lights remained on during the entire session with the exception of the period of feeder presentation. White noise generators provided masking noise at all times, and standard electro-mechanical equipment was programmed to control the experiment and record the data.

Procedure

All birds had had previous experience with autoshaping paradigms. Preliminary training for all subjects consisted of at least 10 days of experience with the autoshaping procedures used at the conclusion of the Brownstein et al. (1977) study. The basic experimental procedure which followed this training consisted of 50 sets of seven trials per day. Each set included 7 presentations of amber-colored key light trials separated by intertrial periods of no key light. The house lights remained on throughout, and grain was presented only after completion of the seventh trial. The proportion of trial length to intertrial length was maintained at a constant value of 1 to 10.

The initial condition consisted of 0.5 second trials separated by 5 second intertrial intervals. The next three conditions were characterized by trial and intertrial durations of 1 and 10 second intertrial durations. Each condition continued for at least 30 days and was terminated when a stable rate of performance was attained.

CHAPTER III

RESULTS

The results presented are based on data collected on the first three and last five days of each condition. One measure recorded as the number of trials with a response. The data presented in Figure 1 are the proportion of trials with a response at each of the seven ordinal trial positions. The data are averaged across all six subjects for the last five days at each interfood interval duration. The data for the 1-second trial duration represent the average of both the initial and reversal 1-second conditions. Key pecking was maintained in patterns generally similar to the positively accelerated patterns generated in response contingent and non-contingent FI discrete trial studies. The cumulative presentation of the above data is shown in Figure 2. Temporal patterns which emerge are representative of those typically characterized in a cumulative format. Figure 3 shows the proportion of trials with a response presented individually for each subject in each condition. The overall pattern of responding characterized by an increased tendency to respond as time to reinforcement approaches, is again evident in the individual data. Mean number of trials with a response is presented cumulatively for each subject in Figure 4. The positively accelerated function which results is most evident for the shortest interval durations. The change in response

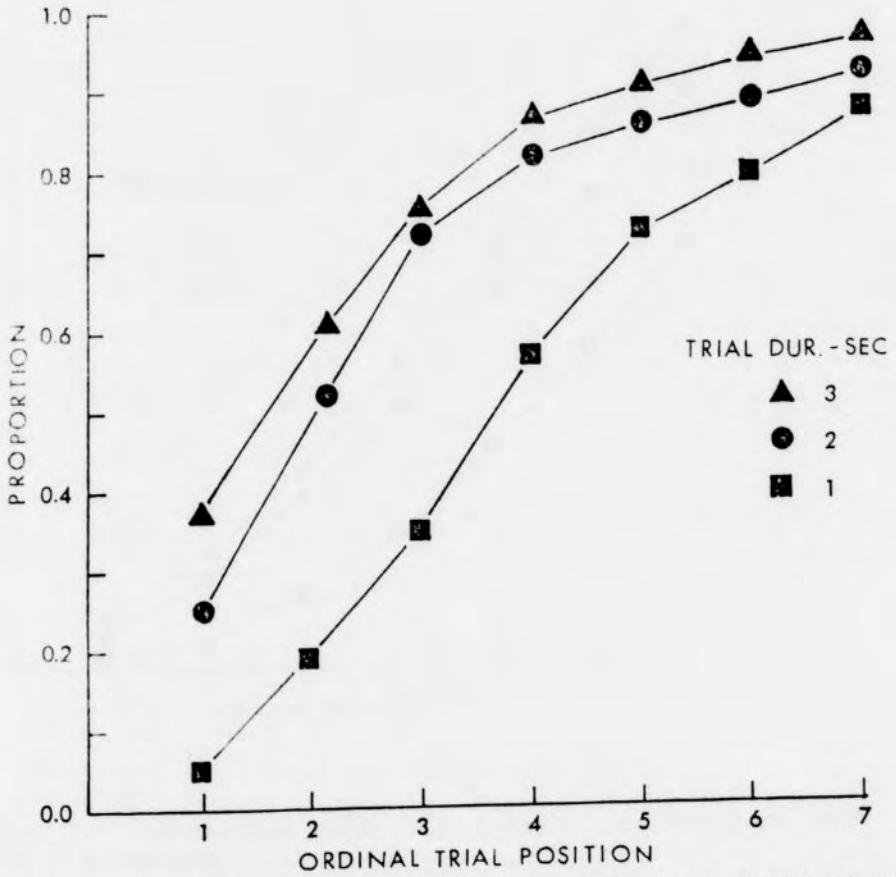

Figure 1. Mean proportions of trials with a response at each ordinal trial position. The 1 sec trial condition in a combination of two determinants in all figures.

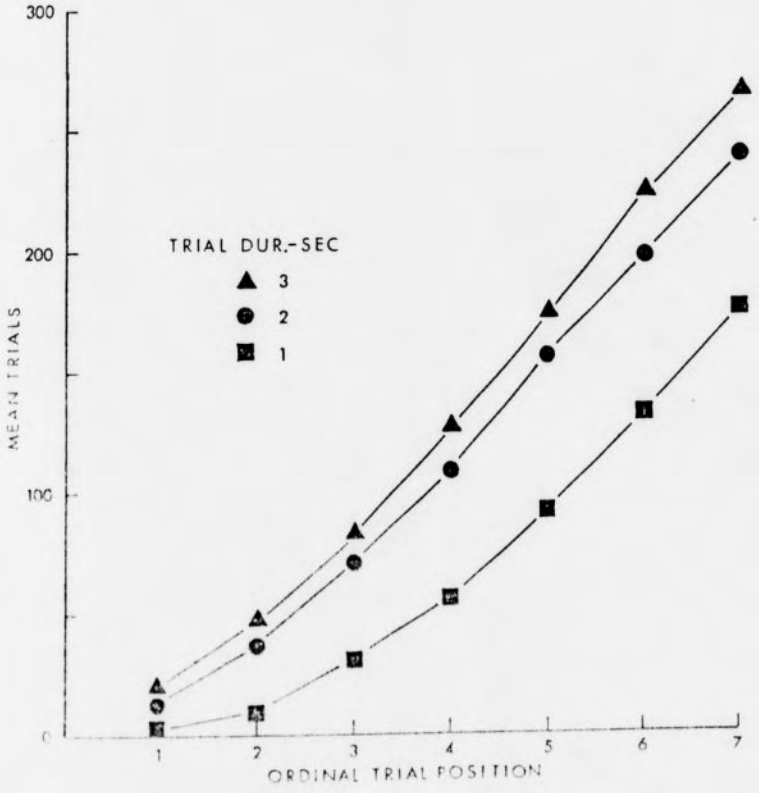

Figure 2. Cumulative mean trials with a response at each ordinal position.

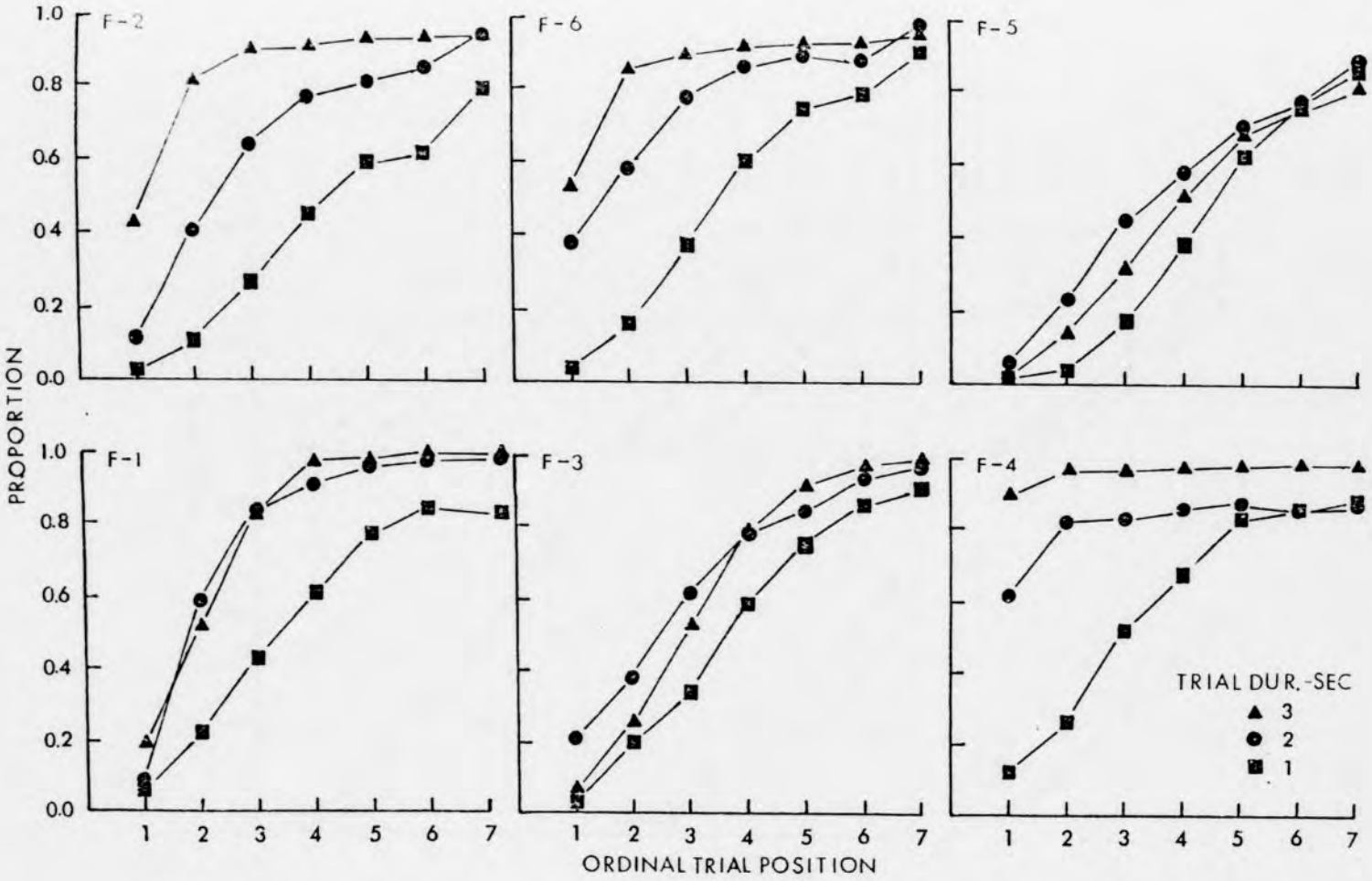

Figure 3. Proportion of trials with a response at each ordinal trial position for individual subjects.

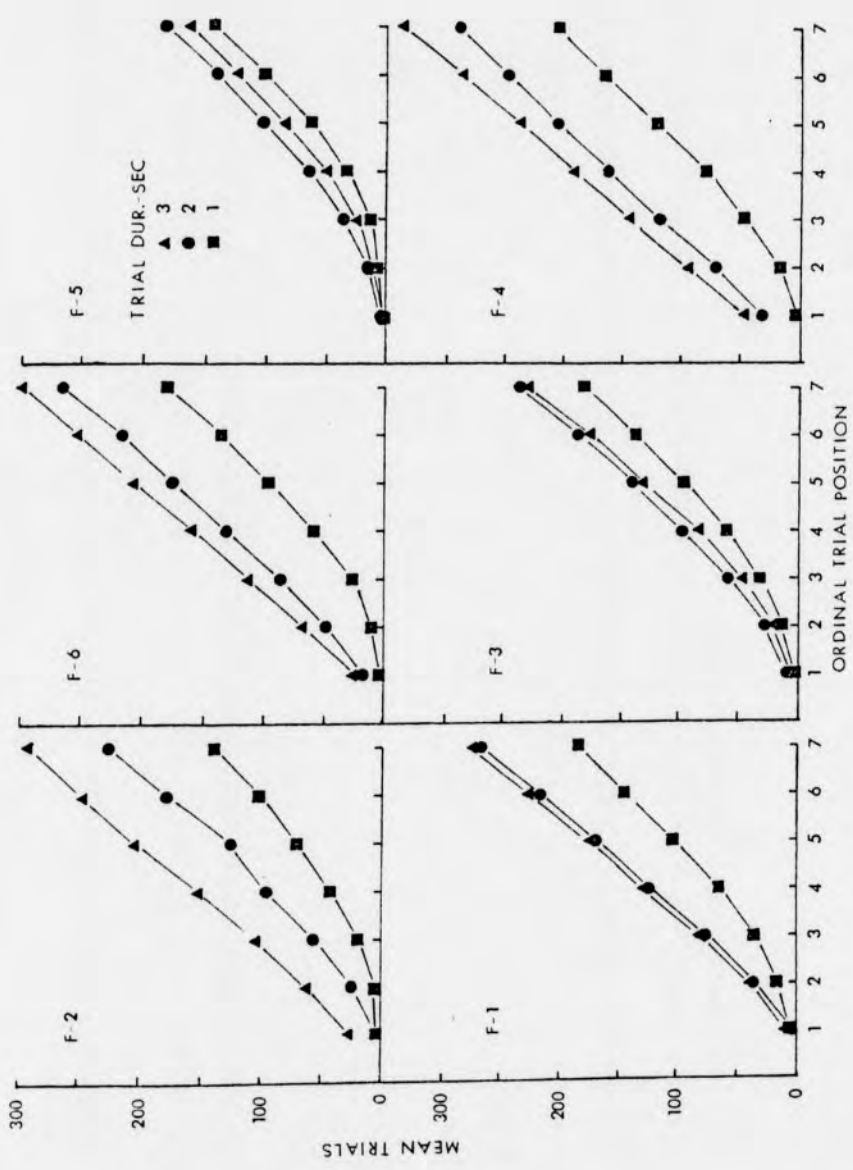

Figure 4. Cumulative mean trials with a response at each ordinal position for individual subjects.

TABLE 1

Indices of Curvature for Trials With a Response
From Last 5 Days in Each Condition

Subjects	Conditions		
	[a]1 sec. trial	2 sec. trial	3 sec. trial
F-1	.30	.19	.18
F-2	.37	.22	.09
F-3	.33	.22	.28
F-4	.26	.04	.01
F-5	.44	.28	.33
F-6	.33	.13	.07
Ave.	.34	.18	.16

a) Combination of 2 determinations.

rate occurs substantially earlier for the longest interfood intervals. One measure commonly used to assess rate of accceleration in fixed interval studies, the index of curvature (Fry, Kelleher, & Cook, 1960), corroborates these observations. The indices summarizing these temporal patterns are presented in Table 1. The table describes the change in the indices of curvature for the last five days of each condition. An index of zero would indicate a straight line for cumulatively plotted data, i.e., a constant proportion of trials with a response at each ordinal position. A lower index indicates less curvature caused by an increase in the probability of responding on early trials. The values are highest for all subjects in the shortest interval condition. The index of curvature values are lower for all subjects on the two-second trial condition. The indices calculated for responding in the three-second condition show the values to be substantially lower than those in the one-second condition and, for 4 of 6 birds, lower values than those calculated for the two-second condition. The decrease in the index of curvature for both individual and group performances suggests a change in temporal control which occurs as the interval is increased. (For a more complete description of the index of curvature, see Frye, Kelleher, and Cook, 1960.)

Rate measures are available for those subjects whose response frequencies were recorded. Figure 5 presents two response rate measures: the frequency of responses per minute of trial time, i.e., overall rate; and rates of responding on those trials in which at least one response was made, designated

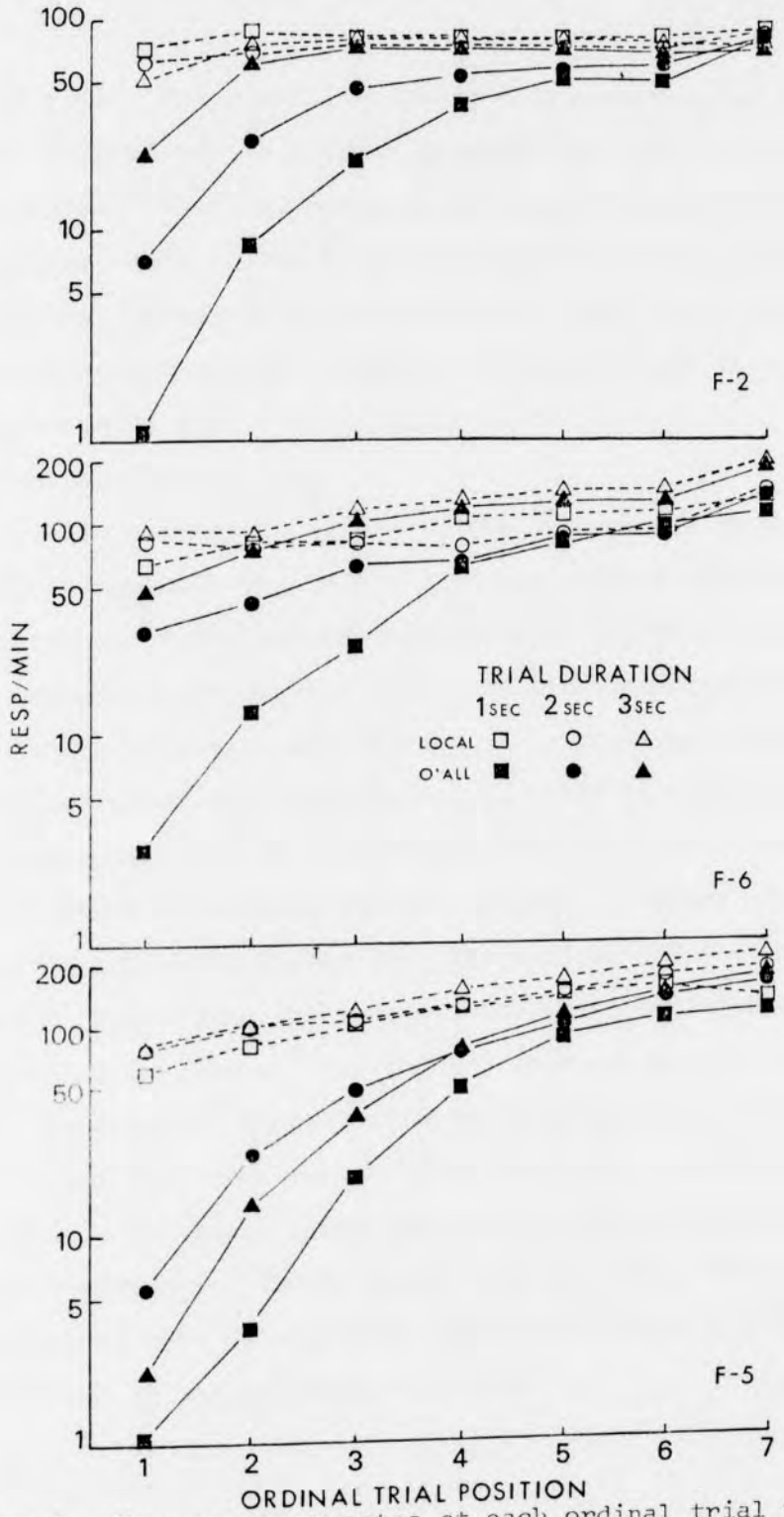

Figure 5. Mean response rates at each ordinal trial position. Overall refer to rates on all trials. Mean rates on trials in which at least one response was made are designated local rates.

local rate. The overall response rate measure also indicates that the tendency to respond increases as time to reinforcement approaches. That is, response rates are lower at the ordinal positions early in the interval than at the terminal trial positions. These data also illustrate that the pattern of responding changes as interfood interval length is increased. Substantially higher rates occur on the early trials for the longest intervals.

Also evident in Figure 5, the differences in local rates on early and late trials are much less marked than the comparable differences in the overall rate measure. That is, given that the animal has responded, there is little acceleration in rate observed across ordinal positions. In addition, when local rates are compared across each condition, there is little difference in rate as a function of interfood interval length. The index of curvature calculated for this response measure corroborates these observations (Table 2). The indices calculated for overall rate again show the greatest curvature during the shortest intertrial condition. The indices continue to vary inversely with the interval length, with the exception of an inversion for S- at the three-second trial condition. Indices of curvature calculated for local rates, however, show no substantial difference among conditions. These values indicate that the positively accelerated rate or scalloped pattern of responding is modulated by whether or not a response occurs.

TABLE 2

Indices of Curvature for Mean Pecks Per Minute
From Last 5 Days In Each Condition

	Trial Conditions					
	[b]Overall Rate			[b]Local Rate		
Subjects	[a]1 sec.	2 sec.	3 sec.	[a]1 sec.	2 sec.	3 sec.
F-2	.39	.26	.11	.04	.05	.04
F-5	.46	.38	.43	.14	.15	.18
F-6	.40	.23	.20	.12	.09	.14

a) Combination of 2 determinations.
b) See text for description of overall and local rates.

Table 3 presents the indices of curvature for trials with a response for the first three and last five days of each condition. The indices for transition periods to longer inter-food intervals are consistently lower than the terminal (last five days) rates for both the prior and the new longer interval condition. Substantially higher values are observed during transition to a shorter interval-reversal condition. These data were provided in order to indicate both the immediate changes in response patterns as a function of varying the trial/intertrial durations and the changes as a function of experience within a particular condition.

Data regarding rate of responding during the ITI are presented in Table 4. Intertrial response rate was generally less than one tenth of the overall response rate. The two subjects with somewhat higher ITI responding, F-3 and F-5, also exhibited the least change in pattern across conditions.

Data for the 0.5-second trial condition (5-second intertrial) were not consistent enough to allow for a complete analysis. Though the available data indicate a higher index of curvature for this condition over the others, direct observation suggested that the subjects did not often appear to have sufficient time to deliver a recordable response.

TABLE 3

Indices of Curvature for Trials With a Response For First Three Days and Last Five Days in Each Condition

	1 sec. trial		2 sec. trial		3 sec. trial		1 sec. trial	
Subjects/Days	First	3-Last 5	First	3-Last 5	First	3-Last 5	First	3-Last 5
F-1	-	.19	.06	.19	.14	.18	.25	.40
F-2	-	.37	.13	.22	.11	.09	.22	.37
F-3	-	.34	.24	.22	.20	.28	.21	.33
F-4	-	.24	.12	.04	.02	.01	.11	.29
F-5	-	.41	.25	.28	.22	.33	.37	.47
F-6	-	.34	.06	.13	.03	.07	.16	.32
Ave.	-	.35	.14	.18	.12	.16	.22	.36

TABLE 4

Ratio of Intertrial Rates of Responding to Overall Trial Rates of Responding

	Trial Condition			
Subject	1 sec.	2 sec.	3 sec.	1 sec.
F-1	.04	.04	.03	.13
F-2	.05	.05	.01	.09
F-3	.01	.15	.12	.09
F-4	.05	.02	.01	.08
F-5	.29	.08	.04	.35
F-6	.02	.03	.03	.04

CHAPTER IV

DISCUSSION

An ordinal effect was observed in that the probability of a response on a particular trial varied as a function of the passage of time. Brownstein and Wetherington (1975b) have observed that absolute interfood interval duration, with trial length remaining constant alters the temporal pattern of responding. Response rate on early trials was seen to increase as a function of interfood interval duration. In this present procedure, with trial to intertrial proportion remaining constant, a similar pattern emerged, i.e., an apparent loss of temporal control as interval duration increased.

The general change in response patterning was characterized by a greater tendency to respond on early trials in the longer interfood intervals. Indices of curvature calculated for two response measures illustrated this change in responding. One measure employed, mean trials with a response, has been utilized as a probability measure in discrete trial fixed interval studies (Heinz and Eckerman, 1974; Nevin, 1969; Schneider and Neuringer, 1972). Although a marked increase in probability of responding on the early trials was observed from these data, this measure did not allow for assessment of increases, possibly proportional, on trials later in the interreinforcement interval. That is, the probability of responding

is already at a maximal level during the first condition. An overall rate measure was taken to examine changes in rate at each trial position. The same general response pattern emerged. Though an increase in terminal trial responding was observed as the interreinforcement interval increased, the rate change was not proportionate to the rate increase seen on early trials. In fact, the overall response rate increases observed across all trial positions could largely be accounted for by increases in response probability, that is, local response rate (rate on trials in which at least one response was made) changed only slightly as a function of interval length. Again, this lack of rate change is corroborated by the index of curvature calculated for local rates.

As mentioned earlier, previous autoshaping experiments have demonstrated an effect of trial/intertrial proportions on the acquisition of key pecking. There is, however, a scarcity of data regarding the effects of this variable on the maintenance of responding. Fragmentary evidence led Hearst and Jenkins (1975) to speculate that response-reinforcer and stimulus-reinforcer relationships interact with temporal parameters in the maintenance of sign-tracking behavior. Manipulations involving trial to interreinforcement interval proportions have demonstrated a general tendency for maintained responding to decrease as trial duration was increased. There are some data to indicate that manipulation of another variable, intermittent pairings of key light and grain, has an effect on maintenance of responding in autoshaping procedures. Ricci (1973) divided the interreinforce-

ment interval into a succession of four differently colored key light presentations. While only two interval lengths were employed, results indicated positively accelerated responding across trials as time to reinforcement approached. This pattern disappeared when the interreinforcement interval consisted of one constant key color.

Hemmendanger (1976) employed a wider range of interfood interval values in a single alternation autoshaping procedure. Every other trial was followed by grain presentation. Trial size remained constant as time between trials was varied. A low rate of responding was observed on the first trial position during the short interval conditions. However, for interfood intervals longer than thirty seconds, the discrimination was observed to break down with the animals responding at the same rates on both reinforced and unreinforced trials. With this procedure, therefore, absolute time appears to have an effect on the patterning of responses.

Discrete trial analogues of fixed interval schedules of reinforcement, as previously mentioned are few, and have, for the most part, dealt with response latency as the primary measure. Schneider and Neuringer (1972) analyzed changes in response frequency, as well as latency, as a function of interval duration. Probability of responding remained low for a time after reinforcement and then increased rapidly about halfway through the interval, to an asymptotic value. This pattern did not change as a function of fixed interval duration - a result

discrepant with that observed in the present study. However, both interval length and number of trials varied conjointly in the Schneider and Neuringer study thus confounding the relationship between fixed interval length and probability of reinforcement on a given trial. Heinz and Eckerman, however, using a similar procedure, separately manipulated the variables trial number and interfood interval duration. Each inter-reinforcement interval was divided into a number of key light on - key light off cycles. With trial size remaining constant three manipulations were performed. In one condition interval duration was held constant and the number of trials was varied. The results showed that the probability of responding on early trials was inversely related to the number of trials per inter-food interval. The next condition held trial number constant and varied interfood interval length. This manipulation resulted in a pattern similar to those observed in this present study, i.e., probability of responding on early trials increased monotonicaly with increases in interval length. In a third condition of interest, interval length and trial number were varied cojointly. An intermediate set of values, FI 2 - 8 trials, produced the highest response frequency early in the interval. Early trial responding decreased for values above and below this intermediate point. These variations in response probability as a joint function of interval length and number of discrete trials were discussed in terms of an interaction of three factors. One factor was described as a conditioned reinforcement gradient associated with each trial position, such that a higher number

of trials results in more trials proximal to reinforcement balanced with more unreinforced trials per reinforcer. This factor would then interact with a relatively constant s like effect which tends to reduce responding on trials immediately after reinforcement. As these trials are moved away in time from reinforcement, as in the constant trial - increasing interval condition, responding will be expected to increase on early trials. The interaction of these factors is seen to be further modulated by a discriminability gradient. That is, with very low numbers of trials discriminability in terms of reinforcement after a particular trial, is high. Large numbers of trials result in a decrease in discriminability and the conditioned reinforcement gradient becomes the more effective controlling variable.

The patterns of responding generated by Heinz and Eckerman manipulation are quite similar to those observed in both the Brownstein and Wetherington and the present study. This similarity suggests control by some common factors. However, the Heinz and Eckerman experiment employed a response-contingent procedure, while the present study utilized noncontingent grain presentation. The appeal to a conditioned reinforcement factor, therefore, may not be necessary. The data generated under both procedures, however, suggest that changes in response cost associated with particular combinations of parameters may produce a shift in behavioral strategies. Assume that the cost of attending to the passage of time increases as the duration of the interfood interval increases. At the same time the response cost associated

with responding on trials increases directly with the number of trials presented. The balancing of these costs is assumed to determine the patterning of responding. For example, the response cost associated with attending to the passage of time in short interval conditions, regardless of the number of trials, in relatively low, hence, temporal patterning would be expected. As the interfood interval increases, with the number of trials remaining constant, the cost in terms of making temporal discriminations also increases. The animal would, therefore, be expected to shift to a discrimination on the basis of the liklihood of grain presentation following each trial and temporal patterning would not be expected. If the interfood interval is held constant at a long duration and as the number of trials increases, the increase in response cost associated with responding on each trial should result in a shift back to a temporal discrimination and a return to temporal patterning. In general, this analysis suggests that in both contingent and non-contingent discrete trial fixed interval schedules, the patterns of responding are determined by the operation of the same behavioral strategies.

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